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(54) **ALL-WHEEL DRIVE FAILSAFE ACTION AXLE TORQUE CALCULATION METHOD**

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G05D 1/00	(2006.01)
B60T 7/12	(2006.01)
B60K 23/08	(2006.01)
F02D 41/02	(2006.01)
F02D 29/02	(2006.01)

(52) **U.S. Cl.**

CPC ***B60K 23/0808*** (2013.01); ***F02D 41/021*** (2013.01); *B60K 2023/085* (2013.01); *F02D 29/02* (2013.01); *F02D 2250/26* (2013.01)

(58) **Field of Classification Search**

USPC 701/1, 87, 88, 89, 90, 91, 92
See application file for complete search history.

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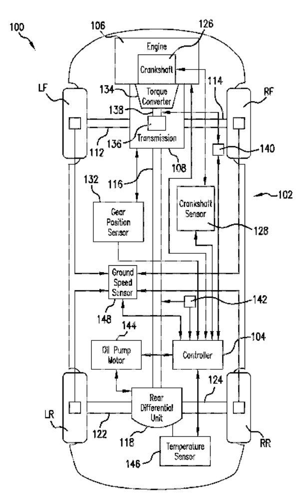
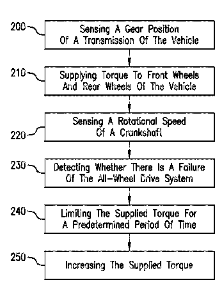
(57) **ABSTRACT**

A method of controlling an all-wheel drive system of a vehicle includes supplying torque to front and rear wheels of the vehicle, sensing a failure of the all-wheel drive system, and adjusting a crankshaft torque of an engine of the vehicle so that the front wheel torque remains constant regardless of a failure of the all-wheel drive system.

16 Claims, 3 Drawing Sheets





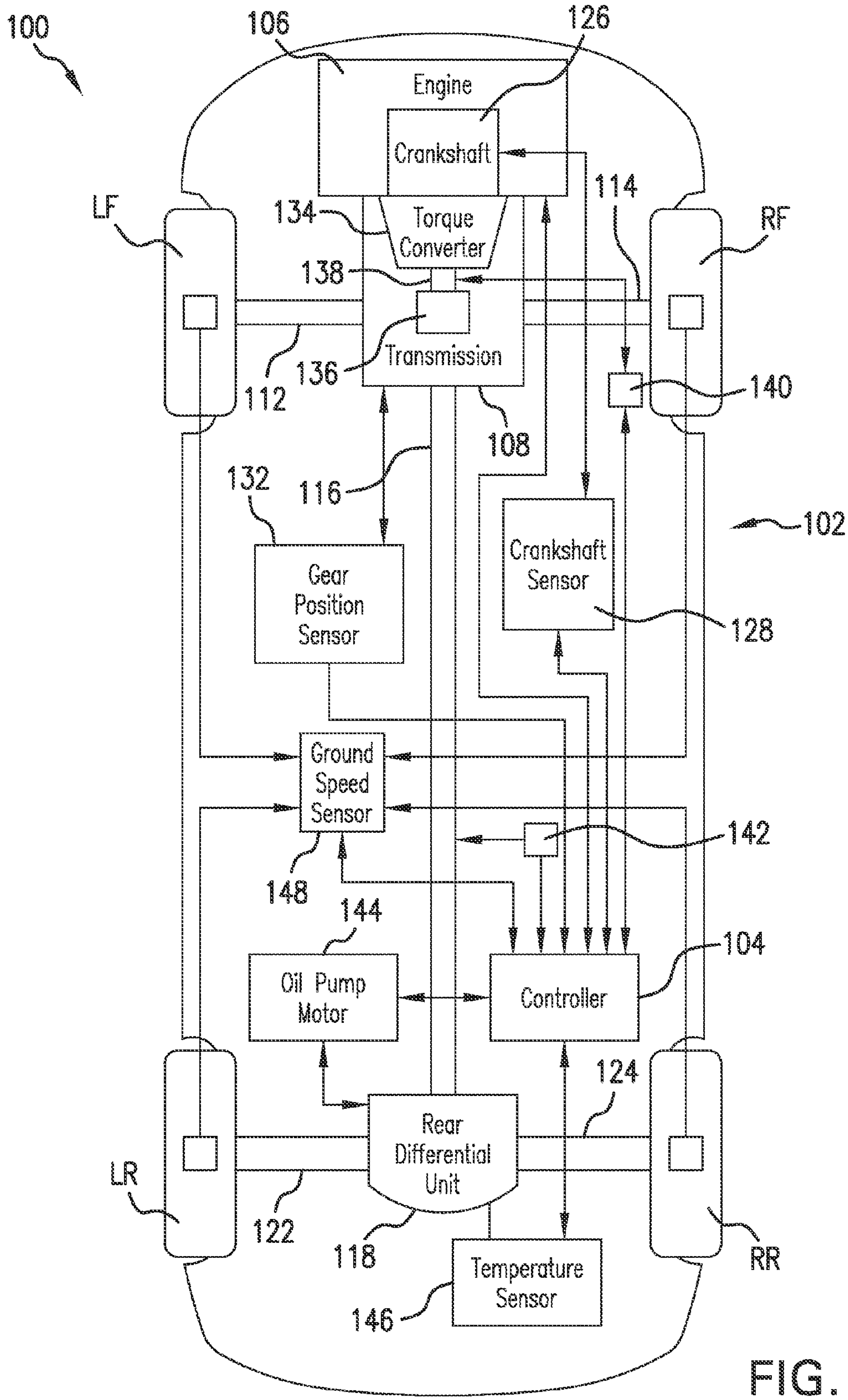

100
106
126
Engine
Crankshaft
114
LF
134
Torque Converter
RF
138
136
Transmission
112
140
108
116
132
102
Crankshaft Sensor
Gear Position Sensor
128
Ground Speed Sensor
142
148
144
104
Oil Pump Motor
Controller
124
Rear Differential Unit
LR
122
118
RR
Temperature Sensor
146

FIG.1

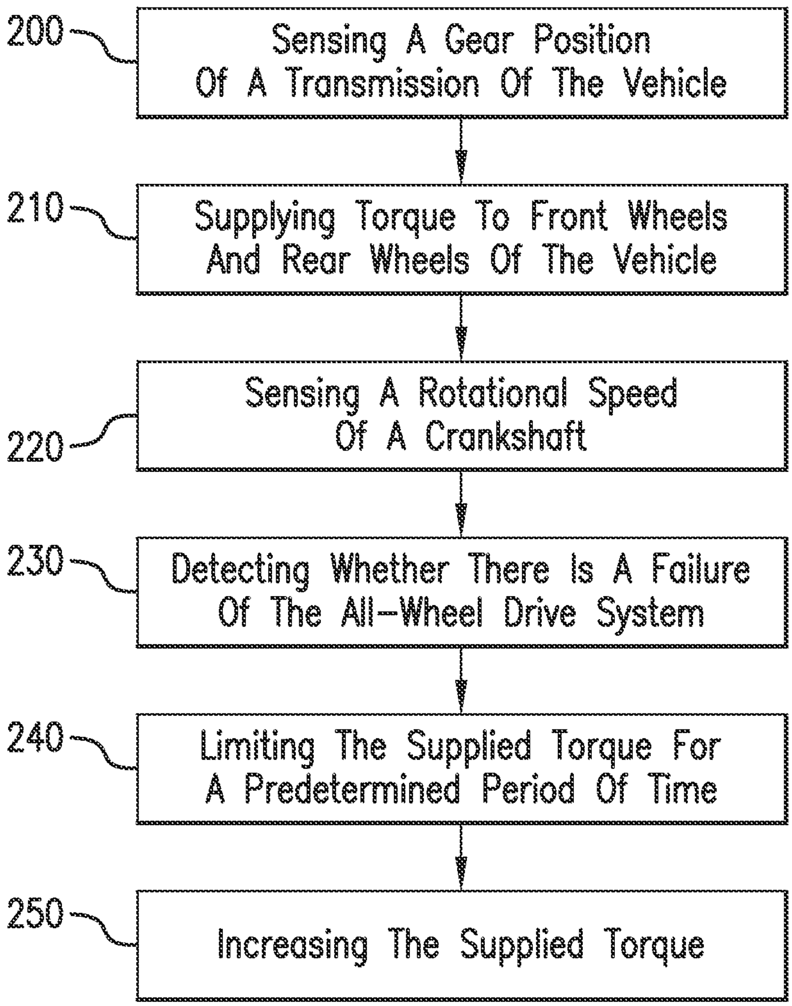

200
Sensing A Gear Position Of A Transmission Of The Vehicle
210
Supplying Torque To Front Wheels And Rear Wheels Of The Vehicle
220
Sensing A Rotational Speed Of A Crankshaft
230
Detecting Whether There Is A Failure Of The All-Wheel Drive System
240
Limiting The Supplied Torque For A Predetermined Period Of Time
250
Increasing The Supplied Torque

FIG. 2

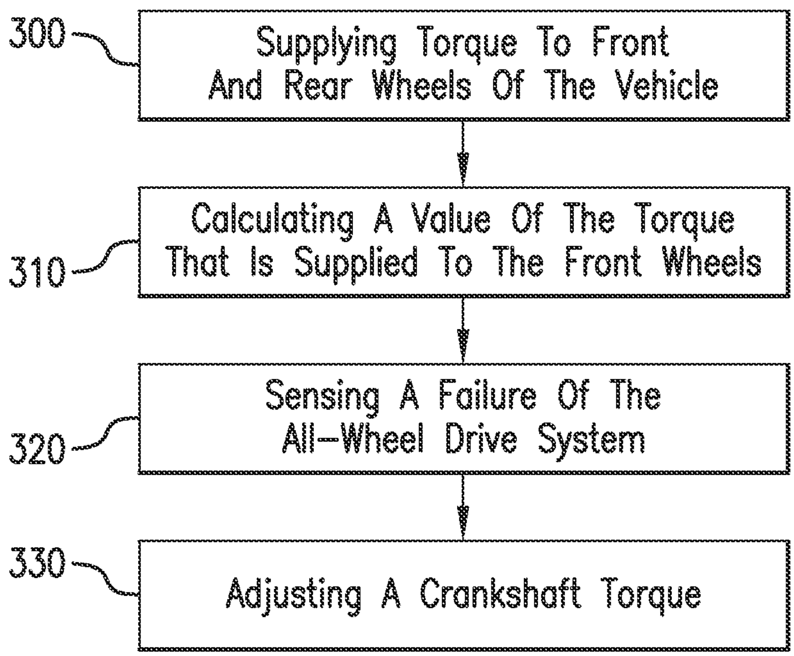

300
Supplying Torque To Front And Rear Wheels Of The Vehicle
310
Calculating A Value Of The Torque That Is Supplied To The Front Wheels
320
Sensing A Failure Of The All-Wheel Drive System
330
Adjusting A Crankshaft Torque

FIG.3

ALL-WHEEL DRIVE FAILSAFE ACTION AXLE TORQUE CALCULATION METHOD

BACKGROUND

An all-wheel drive system can provide increased traction and stability for the vehicle. However, whenever there is a failure of the all-wheel drive system, the vehicle may revert back to a front-wheel drive system. Thus, the torque supplied to the rear wheels is then redistributed to the front wheels, which can cause an increased amount of torque to be supplied to the front wheels. Therefore it is important to determine how the torque should be limited to provide a smooth operation of the vehicle in the event of a failure of the all-wheel drive system.

SUMMARY

According to one aspect, a method of controlling an all-wheel drive system of a vehicle includes supplying torque to front and rear wheels of the vehicle, sensing a failure of the all-wheel drive system, and adjusting a crankshaft torque of an engine of the vehicle so that the front wheel torque remains constant regardless of a failure of the all-wheel drive system.

According to another aspect, a method of controlling a vehicle with an all-wheel drive system includes sensing a gear position of a transmission of the vehicle, supplying torque of a crankshaft of an engine to front wheels and rear wheels of the vehicle, and sensing a rotational speed of the crankshaft. The method also includes detecting whether there is a failure of the all-wheel drive system, and limiting the supplied torque to the front wheels for a predetermined time period after a failure of the all-wheel drive system is detected. The limited torque supplied to the front wheels is based upon the gear position of the transmission and the rotational speed of the crankshaft.

According to a further aspect, a vehicle includes an all-wheel drive system that includes an engine that outputs crankshaft torque through a crankshaft, a transmission that is coupled to the engine and supplies front wheel torque to front wheels of the vehicle, a propeller shaft rotated by the transmission, and a rear differential unit powered by the propeller shaft and supplies rear wheel torque to rear wheels of the vehicle. The vehicle also includes a controller that controls operation of the all-wheel drive system and is configured to receive signals indicative of a failure of the all-wheel drive system. The controller is configured to adjust the crankshaft torque upon receiving a failure signal so that the front wheel torque remains constant during a predetermined time period in which the failure of the all-wheel drive system occurs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic plan view of a vehicle.

FIG. **2** is a flow chart illustrating a method of controlling a vehicle with an all-wheel drive system according to one aspect of the present disclosure.

FIG. **3** is a flow chart illustrating a method of controlling an all-wheel drive system of a vehicle according to another aspect of the present disclosure.

DETAILED DESCRIPTION

It should, of course, be understood the drawing and description herein are merely illustrative and that various modifications and changes can be made in the structures disclosed without departing from the present disclosure. It will be appreciated that the various identified components of the vehicle disclosed herein are merely terms of art that may vary from one manufacturer to another and should not be deemed to limit the present disclosure.

Referring now to FIG. **1**, a vehicle **100** includes an all-wheel drive system **102** that is controlled by a controller **104** to distribute torque from an engine **106** to both front wheels LF, RF and rear wheels LR, RR coupled to the engine **106**. The engine torque is initially supplied to a transmission **108** that provides speed and torque conversions and then transmits the torque to the front wheels LF, RF through front axles **112**, **114**. The front axles **112**, **114** extend in a lateral direction of the vehicle **100**. Suspension and brake components, although not illustrated, can be connected to the front axles **112**, **114**. Additionally, the transmission **108** supplies torque to a propeller shaft **116**. The propeller shaft **116** powers a rear differential unit **118**. The rear differential unit **118** then supplies torque to the rear wheels LR, RR through rear axles **122**, **124**.

The vehicle **100**, as depicted in FIG. **1**, could be any number of vehicles. In particular, the vehicle **100** can be an automobile, a truck, a van, or variants thereof. Further, it will be appreciated that the later described elements and methods could be employed in many other types of vehicles including motorcycles and commercial vehicles without departing from the scope of the disclosure.

The engine **106** schematically depicted in FIG. **1** can be of a single cylinder or multi-cylinder arrangement. Further, the engine **106** can be powered by any number of fuels including, for example, gasoline, diesel, and natural gas. Further still, the engine **106** could be powered by a single fuel or by a plurality of fuels. Additionally, the engine **106** can be of a hybrid-type arrangement. The engine **106** may operate in ranges from approximately 600 revolutions per minute to over 7,000 revolutions per minute, if fueled by gasoline. Naturally, if the engine **106** were fueled by diesel, lower operating ranges would be expected. Although the engine **106** is illustrated as being disposed in a front part of the vehicle **100**, it is envisioned that the engine **106** could be located in other parts of the vehicle **100** without departing from the scope of the disclosure. The engine **106** is connected to the controller **104** so that various operating parameters of the engine **106** may be monitored and controlled by the controller **104**. The engine **106** may be oriented in a longitudinal or transverse position in the vehicle **100**.

The engine **106** outputs torque through a crankshaft **126** as is known in the art. A crankshaft sensor **128** may be disposed near the crankshaft **126** to measure a rotational speed of the crankshaft **126**. The crankshaft sensor **128** may use any number of contact or non-contact type technologies for sensing the rotational speed of the crankshaft **126**. The crankshaft sensor **128** can be connected to the controller **104** for communication therebetween.

The transmission **108** can include a gear position sensor **132** which senses a gear position of the transmission **108**. Naturally, the higher the gear selected for the vehicle **100**, the faster of a ground speed for the vehicle is possible. The gear position sensor **132** communicates with the controller **104** as will be described hereinafter. The gear position sensor **132** may sense the gear position of the transmission **108** of the vehicle **100** by any number of techniques known in the art. The gear position sensor **132** may be proximal to the transmission **108** or may be disposed in other locations of the vehicle **100**.

The transmission **108** can also include a torque converter **134**. The torque converter **134** can be a type of fluid coupling that is used to transfer the torque from the engine **106** to the front and rear wheels LF, RF, LR, RR, as is known in the art. The torque converter **134** is configured to multiply torque when there is a substantial difference between input and output rotational speeds of the engine **106** and the front and rear wheels LF, RF, LR, RR. Therefore, the torque converter **134** can function as a reduction gear.

Also within the transmission **108** is a gear train **136**. The gear train **136** serves to translate the rotational speed of the crankshaft **126** into a rotational speed that is acceptable for the front and rear wheels LF, RF, LR, RR. For simplicity, the gear train **136** is not illustrated in detail. However, it will be appreciated that the gear train **136** can be comprised of a plurality of gears in a known arrangement.

A connecting shaft **138** longitudinally extends between the gear train **136** and the torque converter **134** for the transmission of torque. Further, a shaft sensor **140** is disposed so as to sense a rotational speed of the connecting shaft **138**. Like the crankshaft sensor **128**, the shaft sensor **140** may be of a contact or non-contact type. The shaft sensor **140** is connected to the controller **104** as will be described later.

Although the transmission **108** has been described as being an automatic transmission, in view of the torque converter **134**, it will be appreciated that a manual transmission could be used in place of an automatic transmission without departing from the scope of the disclosure. Further, it is envisioned that the present disclosure could also encompass a vehicle with a semi-automatic transmission in which the driver of the vehicle selects the desired gear, but the clutch is automatically engaged as needed.

As illustrated, the transmission outputs torque to a plurality of sources. Specifically, the transmission **108** outputs torque to the left front axle **112** and the right front axle **114**. The transmission **108** also transmits torque to the propeller shaft **116**. The propeller shaft **116** is illustrated as being located in a laterally central portion of the vehicle **100** and extends in a longitudinal direction of the vehicle **100**. The propeller shaft **116** can be a torque tube with a single universal joint or a Hotchkiss drive with two or more joints. The propeller shaft **116** serves to transfer rotational energy between the transmission **108** and the rear differential unit **118**. A transmission output shaft sensor **142** can be mounted near the propeller shaft **116** so as to measure a rotational speed of the propeller shaft **116**. The transmission output shaft sensor **142** is connected to the controller **104**. The transmission output shaft sensor **142** can also be of a contact or non-contact type, which is known in the art.

With continued attention to FIG. **1**, the rear differential unit **118** receives rotational energy from the propeller shaft **116**. Additionally, the rear differential unit **118** outputs torque to the left rear axle **122** and the right rear axle **124** to rotate the rear wheels LR, RR, respectively. The rear axles **122**, **124** extend in the lateral direction of the vehicle **100**. As will be appreciated various types of braking and suspension components could be attached to the axles **122**, **124**. The rear differential unit **118** can include a number of gears which are not illustrated. The rear differential unit **118** can also include a number of clutches. This arrangement allows the left rear wheel LR to spin at a different rotational rate than the right rear wheel RR.

An oil pump motor **144** can be associated with the rear differential unit **118**. The oil pump motor **144** can supply fluid to the rear differential unit **118** for operational purposes. Further, the oil pump motor **144** may be connected to

the controller **104** so as to allow data communication therebetween. By connecting the oil pump motor **144** to the controller **104**, the controller **104** can monitor and control the oil pump motor **144** for optimal operation.

A temperature sensor **146** can be provided to the rear differential unit **118**. The temperature sensor **146** can sense a temperature within the rear differential unit **118**. The temperature sensor **146** is connected to the controller **104** and can provide this temperature data to the controller **104**. The temperature information can be used by the controller **104** to determine if the all-wheel drive system **102** is in a failure mode. The sensor **146** can be of a contact or non-contact type.

The vehicle **100** can also include a ground speed sensor **148**. As illustrated, the ground speed sensor **148** is a single component that is connected to the controller **104**. However, it will be appreciated that the ground speed sensor **148** could alternatively be a number of units that are connected to the controller **104**. As illustrated, the ground speed sensor **148** is connected to sense rotational speed of the front and rear wheels LF, RF, LR, RR. However, other techniques are also possible. For example, the ground speed sensor **148** could utilize various types of non-contact means for determining a speed of the vehicle **100**, such as, a global positioning system module.

FIG. **1** shows the four wheels LF, RF, LR, RR disposed at near corners of the vehicle **100**. However, the front and rear wheels LF, RF, LR, RR could be located laterally inward/outward and longitudinally inward/outward from the location illustrated without departing from the scope of the disclosure. It would be expected that the front and rear wheels LF, RF, LR, RR could rotate between zero and approximately 1,800 revolutions per minute. While the front wheels LF, RF are illustrated as being a same lateral distance apart as the rear wheels LR, RR, it will be appreciated that a distance between the front wheels LF, RF could be different than a distance between the rear wheels LR, RR, i.e., in a staggered arrangement.

The vehicle **100** also includes the controller **104** that among other things controls the all-wheel drive system **102**. As illustrated, the controller **104** is located near a rear end of the vehicle **100**. However, the controller **104** could be located in any number of places in the vehicle **100** without departing from the scope of this disclosure. The controller **104** is connected to the engine **106**, the crankshaft sensor **128**, the gear position sensor **132**, the shaft sensor **140**, the transmission output shaft sensor **142**, the oil pump motor **144**, the temperature sensor **146**, and the ground speed sensor **148** so as to allow two way communication between the controller **104** and the described components. Further, although shown as being connected to the various components with wires, it will be understood that the controller **104** could be interfaced with the other components through a variety of other connection methods including, for example, wireless communication. The controller **104** may be any number of central processing units or programmable logic controllers.

With regard to control of the all-wheel drive system **102**, the controller **104** is able to adjust the torque from the crankshaft **126** whenever the controller **104** determines that at least one component of the all-wheel drive system **102** has failed so that the front wheel torque, i.e., the torque supplied to the front wheels LF, RF, remains substantially constant. The controller **104** is able to determine if the all-wheel drive system **102** is in a failure mode based at least upon the signals received from the engine **106**, the crankshaft sensor **128**, the gear position sensor **132**, the shaft sensor **140**, the transmission output shaft sensor **142**, the oil pump motor **144**, the temperature sensor **146**, and the ground speed sensor **148**. It will be appreciated that the controller **104** could also determine that the all-wheel drive system **102** is in a failure mode based upon other signals received from different sensors not specifically described herein.

The controller **104** is configured to adjust the torque output from the crankshaft **126** of the engine **106** upon receiving what the controller **104** determines to be a failure signal so that the torque of the front wheels LF, RF remains approximately constant, by according to one aspect, determining the adjusted crankshaft torque with the following equation: ACT=CFWT/(GR×E)/TCG. The symbol ACT equals the adjusted crankshaft torque, the symbol CFWT equals a calculated front wheel torque, the symbol GR equals a transmission gear ratio, the symbol E equals a transmission efficiency, and the symbol TCG equals a torque converter gain.

The controller **104** controls the all-wheel drive system **102** so that a value of the rear wheel torque, i.e., the torque at the rear wheels LR, RR, equals approximately zero subsequent to the controller **104** determining that the all-wheel drive system **102** has failed. Thus, the torque supplied to the front wheels LF, RF is greater than the torque supplied to the rear wheels LR, RR. The controller **104** is configured to adjust the torque from the crankshaft **126** by adjusting operating parameters of the engine **106**. For example, to reduce the torque from the crankshaft **126**, the controller **104** could reduce the amount of fuel supplied to the engine **106** or retard the timing of the engine **106**. By reducing the crankshaft torque, the controller **104** ensures that the front wheels LF, RF do not receive a dramatic increase in torque when the torque originally destined for the rear wheels LR, RR is redistributed to the front wheels when the all-wheel drive system **102** fails.

The controller **104** can include a number of look-up tables. These look-up tables may include the transmission gear ratio, the transmission efficiency, and the torque converter gain. The torque converter gain is based upon a rotational speed of the torque converter **134**. The rotational speed of the torque converter **134** can be determined either from actual measurement or by calculation. The controller **104** is also configured to calculate the front wheel torque based upon the gear position and the crankshaft torque. The gear position is determined based upon a signal received from the gear position sensor **132** and the crankshaft torque is determined based upon a signal from the crankshaft sensor **128**.

With reference to FIGS. **2** and **3**, a method of controlling a vehicle with an all-wheel drive system and a method of controlling an all-wheel drive system of a vehicle, are shown. While, for purposes of simplicity of explanation, the methods have steps shown and described as executing serially, it is to be understood and appreciated that the present invention is not limited by the illustrated order, as some steps could occur in different orders and/or concurrently with other steps from those shown and described herein.

With reference to FIG. **2**, an exemplary method of controlling the vehicle **100** with the all-wheel drive system **102** is illustrated. In Step **200**, a gear position of the transmission **108** is determined by the controller **104** receiving a gear position signal from the gear position sensor **132**. In Step **210**, torque is supplied to front wheels LF, RF and rear wheels LR, RR in a manner as previously described. In Step **220**, a rotational speed of the crankshaft **126** is sensed by the crankshaft sensor **128**. By sensing the rotational speed of the crankshaft **126**, the controller **104** can determine the engine torque. In Step **230**, detection of whether there is a failure of the all-wheel drive system **102** occurs by the controller **104** analyzing the signals received from the engine **106**, the crankshaft sensor **128**, the gear position sensor **132**, the shaft sensor **140**, the transmission output shaft sensor **142**, the oil pump motor **144**, the temperature sensor **146**, and the ground speed sensor **148**. In Step **240**, the supplied torque to the front and rear wheels LF, RF, LR, RR is limited for a predetermined period of time after a failure of the all-wheel drive system **102** is detected. The torque can be limited by adjusting the rotational speed of the crankshaft **126**. As will be appreciated, the rotational speed of the crankshaft **126** is not directly controlled. Rather, the rotational speed of the crankshaft **126** is indirectly controlled by any number of methods, including for example, by adjusting throttle, by adjusting fuel injection, and/or by adjusting spark timing. Further, the limited torque supplied to the front wheels LF, RF is based upon the gear position of the vehicle **100** and the torque output from the crankshaft **128**. The predetermined time period can be anywhere from one to approximately five seconds, with a general duration of about three seconds. This provides a sufficient time for the driver of the vehicle **100** to adjust to the failure of the all-wheel drive system **102**. By taking into account the gear position of the transmission **108** and the amount of torque output by the crankshaft **126**, the proper amount of torque can be supplied to the front wheels LF, RF, thereby ensuring smooth operation of the vehicle **100**.

The limited torque supplied to the rear wheels LR, RR during the predetermined period of time is equal to approximately zero. After the predetermined time period, the torque from the crankshaft **126** is increased at a predetermined rate until it is equal to the crankshaft torque prior to the failure of the all-wheel drive system **102**. Naturally, this outcome is based upon no other system or diver-input changes. According to one aspect, this predetermined rate is about 1.5 Newton-meters per ten milliseconds. It is noted that the crankshaft torque can be controlled by controlling the rotational speed of the crankshaft **126** with the controller **104**, as described hereinbefore.

With reference to FIG. **3**, an exemplary method of controlling the all-wheel drive system **102** with the vehicle **100** is shown. In Step **300**, torque is supplied to the front and rear wheels LF, RF, LR, RR of the vehicle **100** in a manner as previously described. In Step **310**, a value of the torque that is supplied to the front wheels LF, RF is calculated based upon the signals received by the controller **104** from the gear position sensor **132** and the crankshaft sensor **128**. In Step **320**, a failure of the all-wheel drive system **102** is sensed by the controller **104** analyzing the signals received from the engine **106**, the crankshaft sensor **128**, the gear position sensor **132**, the shaft sensor **140**, the transmission output shaft sensor **142**, the oil pump motor **144**, the temperature sensor **146**, and the ground speed sensor **148**. In Step **330**, the torque supplied by the crankshaft **126** of the engine **106** is adjusted so that the front wheel torque remains constant regardless of the failure of the all-wheel drive system **102**. The crankshaft torque can be adjusting by changing the rotational speed of the crankshaft **126**. The torque supplied to the front wheels LF, RF subsequent to a failure of the all-wheel drive system **102** is greater than the torque supplied to the rear wheels LR, RR subsequent to a failure of the all-wheel drive system **102**. The crankshaft torque may be adjusted so that a value of the torque supplied to the rear wheels LR, RR subsequent to a failure of the all-wheel drive system **102** is equal to approximately zero. Further, the adjusted crankshaft torque can be determined based upon the calculated front wheel torque. The transmission gear ratio, the transaxle efficiency, and the torque converter gain can be determined from the look-up table. The torque converter gain is based upon a rotational speed of the torque converter **134** of the vehicle **100**.

It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

The invention claimed is:

1. A method of controlling an all-wheel drive system of a vehicle, comprising:

supplying torque from an engine of the vehicle to front and rear wheels of the vehicle;

sensing a failure of the all-wheel drive system with a sensor;

adjusting a crankshaft torque of the engine with a controller so that the front wheel torque remains constant regardless of a failure of the all-wheel drive system;

calculating a value of the torque that is supplied to the front wheels prior to a failure of the all-wheel drive system; and

determining the adjusted crankshaft torque based upon the calculated front wheel torque.

2. The method of controlling an all-wheel drive system of a vehicle of claim **1**, wherein the torque supplied to the front wheels subsequent to a failure of the all-wheel drive system is greater than the torque supplied to the rear wheels subsequent to a failure of the all-wheel drive system.

3. The method of controlling an all-wheel drive system of a vehicle of claim **2**, further including

adjusting the crankshaft torque so that a value of the torque supplied to the rear wheels subsequent to a failure of the all-wheel drive system is equal to zero.

4. The method of controlling an all-wheel drive system of a vehicle of claim **1**, wherein the adjusted crankshaft torque is determined by the equation: $ACT=CFWT/(GR\times E)/TCG$, and wherein ACT equals the adjusted crankshaft torque, CFWT equals a calculated front wheel torque, GR equals a transmission gear ratio, E equals a transmission efficiency, and TCG equals a torque converter gain.

5. The method of controlling an all-wheel drive system of a vehicle of claim **4**, further including

determining the transmission gear ratio, the transmission efficiency, and the torque converter gain from a look-up table, wherein the torque converter gain is based upon a rotational speed of a torque converter of the vehicle.

6. The method of controlling an all-wheel drive system of a vehicle of claim **4**, wherein the calculated front wheel torque is based upon a crankshaft torque of the vehicle and a gear position of a transmission of the vehicle.

7. A method of controlling a vehicle with an all-wheel drive system, comprising:

sensing a gear position of a transmission of the vehicle;

supplying torque of a crankshaft of an engine to front wheels and rear wheels of the vehicle;

sensing a rotational speed of the crankshaft;

detecting whether there is a failure of the all-wheel drive system with a sensor; and

limiting the supplied torque to the front wheels for a predetermined time period after a failure of the all-wheel drive system is detected, wherein the limited torque supplied to the front wheels is based upon the gear position of the transmission and the rotational speed of the crankshaft, wherein the limited torque supplied to the rear wheels during the predetermined time period is equal to zero, and wherein subsequent to the predetermined time period, the crankshaft torque is increased at a predetermined rate until being equal to the crankshaft torque prior to the failure of the all-wheel drive system.

8. The method of controlling an all-wheel drive system of a vehicle of claim **7**, wherein the predetermined time period is about three seconds.

9. The method of controlling an all-wheel drive system of a vehicle of claim **7**, wherein the predetermined rate is about 1.5 Newton-meters per 10 milliseconds.

10. The method of controlling an all-wheel drive system of a vehicle of claim **7**, wherein the limited torque supplied to the front wheels is controlled by reducing a rotational speed of an engine of the vehicle.

11. A vehicle, comprising:

an all-wheel drive system including

an engine that outputs crankshaft torque through a crankshaft,

a transmission that is coupled to the engine and supplies front wheel torque to front wheels of the vehicle,

a propeller shaft rotated by the transmission, and

a rear differential unit powered by the propeller shaft and supplies rear wheel torque to rear wheels of the vehicle;

an oil pump motor associated with the rear differential unit;

a temperature sensor that is configured to sense a temperature within the rear differential unit; and

a controller that controls operation of the all-wheel drive system and is configured to receive signals indicative of a failure of the all-wheel drive system, wherein the controller is configured to adjust the crankshaft torque upon receiving a failure signal so that the front wheel torque remains constant during a predetermined time period in which the failure of the all-wheel drive system occurs, wherein the controller is configured to receive signals from the oil pump motor and the temperature sensor, and wherein the controller is configured to determine if a failure of the all-wheel drive system has occurred based upon the signals from the oil pump motor and the temperature sensor.

12. The vehicle of claim **11**, wherein the controller adjusts the crankshaft torque upon receiving a failure signal so that the front wheel torque remains constant by determining the adjusted crankshaft torque with the equation: $ACT=CFWT/(GR\times E)/TCG$, and wherein ACT equals the adjusted crankshaft torque, CFWT equals a calculated front wheel torque, GR equals a transmission gear ratio, E equals a transmission efficiency, and TCG equals a torque converter gain.

13. The vehicle of claim **12**, further including a torque converter disposed in the transmission and a torque converter speed sensor configured to sense a rotational speed of the torque converter and send a signal indicative of the rotational speed of the torque converter to the controller.

14. The vehicle of claim **13**, wherein the controller includes a lookup table including a transmission gear ratio, a transmission efficiency, and a torque converter gain, and wherein the torque converter gain is based upon the torque converter rotational speed signal.

15. The vehicle of claim 12, further including
a gear position sensor configured to sense a gear position of the transmission and send a gear position signal to the controller, and
a crankshaft sensor configured to sense a rotational speed of the crankshaft and send a crankshaft speed signal to the controller, wherein the controller is configured to calculate front wheel torque based upon the gear position signal and the crankshaft speed signal.

16. The vehicle of claim 11, wherein the controller controls the all-wheel drive system so that a value of the rear wheel torque equals zero subsequent to the controller receiving a signal indicative of a failure of the all-wheel drive system.

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